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Dental laser safety

Pamela J. Piccione, RDA

1690 Woodside Road, Redwood City, CA 94061, USA

Safety is an integral part of providing dental treatment with a laser instrument. The subject covers many topics including regulations and hazard recognition that affect the device, environment, surgical team, and target tissue of the patient. The author assumes that the dental practitioner is trained to use a specific laser device in accordance with the standard of care.

There are three facets to laser safety: (1) the manufacturing process of the instrument, (2) proper operation of the device, and (3) the personal protection of the surgical team and the patient.

Before activating a laser, a practitioner likely will have many questions about how to operate the instrument safely. Where can practitioners find information about using dental lasers safely? Other than recommendations given by colleagues, how can the practitioner be reassured that he or she is employing safe laser practices? It is fortunate that the dental industry globally has regulatory agencies to mandate and guide the dental professional and dental laser manufacturers.

Regulatory agencies

In addition to various state governments, the United States has four major organizations that are concerned with regulations regarding the safety of laser systems: the American National Standards Institute (ANSI); the Food and Drug Administration (FDA) and its regulatory bureau, the Center for Devices and Radiological Health (CDRH); and the Occupational Safety and Health Administration (OSHA).

The FDA, through the CDRH, regulates the laser manufacturer, ensuring compliance with medical device legislation [1]. A laser manufacturer must prove the safety and efficacy of that specific device and dental

E-mail address: pampiccione@yahoo.com

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procedure. When safety and efficacy is demonstrated adequately, marketing clearance is awarded for that device and procedure only. After the CDRH awards marketing clearance [510 (k)] to a laser manufacturer, the device can be sold in the United States [2].

The CDRH also sets standards for light-emitting products [3]. In the United States, certain safety features must be included in the manufacturing of a laser device. To be compliant, the manufacturers must include a key lock switch, a laser emission indicator, a remote interlock connector, protective housing, safety interlocks, location of controls (control panel), a power display, a safety shutter, a manual reset, system time out, a laser stop button, self-diagnostics, a footswitch cage, separate enable and disable buttons, lockable casters (for those machines with wheels), and sterilizable tips or handpieces and fibers (for those with fiber-optic delivery systems.)

It should be noted that although the FDA is an organization whose jurisdiction encompasses the United States, its standards and other concepts strongly influence regulatory agencies in other countries.

OSHA regulates workplaces for employee safety [4]. An environment that ignores OSHA regulations is in potential risk of severe fines and restrictions. The office or surgical location must have written policies of the standard operating procedures that take into account the laser beam and nonbeam hazards. Laser educational programs should be included and must be available within the practice setting. The policy manual should be reviewed annually and revised if warranted to conform to current standards, procedures, and instrumentation.

ANSI, an organization of industry experts, provides guidance for the safe use of lasers and laser systems by defining control measures for all laser classifications [5,6]. Technical information on measurements, calculations, and biologic effects with the use of lasers in health care facilities is inclusive in the current standard, Z136.1 and Z136.3. The ANSI Standard is an excellent reference for dental practitioners and could be considered a "must have" by anyone using or considering the use of dental lasers. ANSI also is responsible for creating and defining the role and responsibilities of the laser safety officer (LSO) in the Z136.3 version of the ANSI Standard. Because of the importance of having the safety practices in place, however, the LSO position also is discussed in the Z136.1 version.

Although there are many laser safety standards that coexist across the world, some requirements may differ, particularly with respect to signs, symbols, and control measures. Anyone using a dental laser should first review with the national, state, or local regulatory agencies.

Laser classification

Laser classifications are based chiefly on the potential of the primary laser beam or the reflected beam to cause biologic damage to the eyes or skin. The ANSI Standard Z136.1–2000 documents the set standards for classification

in the United States. OSHA and the American Conference of Governmental Industrial Hygienists also use this standard as a source. Other countries subscribe to these standards and have their own similar regulatory agencies.

There are four general classes of lasers; the higher the classification number, the greater the potential hazard. The classes are differentiated by a combination of the output power of continuous emission lasers or energy per pulse for pulsed lasers and the amount of time that the beam is viewed.

Class I

Lasers in this category working under normal operating conditions do not pose a health hazard. These devices usually are totally enclosed, and the beam does not exit the housing. A CD player would be an example. The output power of a class I laser is measured in tenths of milliwatts.

Class II

Lasers in this category emit only visible light with low power output and do not normally pose a hazard because of the normal human blinking and aversion reactions. A supermarket bar code scanner, and some small laser pointers demonstrate this class. The maximum allowable output power of these devices is 1 mW. There are two subclasses: class IIa is hazardous when directly viewed for longer than 1000 seconds; class IIb has a dangerous viewing time of one fourth of a second, which is the length of time of an ordinary blinking reflex.

Class IIIa

Lasers in this category can emit any wavelength and have output power less than 0.5 W of visible light, or approximately 0.1 to 0.2 W in the other portions of the electromagnetic spectrum. In this class, when the laser light is viewed only momentarily (within the aversion response period or blinking reflex—one-fourth of a second), it will not harm the unprotected eye. These lasers have a caution label on them.

Class IIIb

These lasers can produce a hazard to the unprotected eye if viewed directly or viewed from reflective light for any duration. The output power can be no greater than 0.5 W of any electromagnetic radiation. Class IIIb lasers will not cause reflective hazards when using matted (not shiny) surfaces and do not normally produce fire hazards. An argon curing laser, only if set at less than 0.5 W, would exemplify this type of device. Low-level therapeutic lasers would be class IIIa or class IIIb, depending on the emission wavelength and the duration of exposure. Because these lasers usually have dental treatment time measured in minutes, eye protection must be used.

Class IV

This category of lasers is hazardous from direct viewing and may produce hazardous diffuse reflections. Any output power greater than 0.5 W measured in either continuous wave or pulsed emission constitutes a class IV laser. These devices also produce fire and skin hazards.

The lasers presently used in dentistry are class IIIb or class IV; therefore, they present the possibility of serious eye and skin damage. Class IV lasers also may ignite flammable objects (such as alcohol-moistened gauze) and may create hazardous airborne contaminants.

It must be emphasized that the human blinking and aversion reflexes will not serve as eye protection when using dental laser instruments. Therefore, the appropriate laser safety glasses for the wavelength used must be worn while the laser is on. Eye protection is discussed later in this article.

Clearly, other factors such as the conditions under which a laser is used, the level of safety training of individuals using the lasers, and other environmental factors are important in determining the required safety control measures.

Laser safety officer

An LSO is defined by worldwide standards as being a designated, trained person who directs laser safety practices and ensures a safe environment while a laser is in use [5,7].

Who can be an LSO? One suggestion is a chair-side dental assistant. There are many responsibilities of an LSO; most, if not all, naturally fall under the assistant's job description. It is unfortunate that this person might translate laser dentistry, with its newly added duties, into extra work. In conversations with many clinicians, one recurring theme is that they would like their auxiliaries to be more enthusiastic about laser dentistry, to become more involved, and to be excited to promote the technology. The simple response is education. Each practitioner needs an LSO, and the LSO needs training/education through an accredited safety program. The more the assistant understands the clinical procedures, the science of laser physics, and the patient benefits, the more that person becomes a team player. The result: less resistance, more assistance.

The role and performance of the LSO is vital for the safe use of lasers in dentistry. A designated LSO must be present during any procedure using a class IIIb or class IV laser.

The following are the responsibilities of the LSO, not listed in order of importance or priority; moreover, these responsibilities are valued equally and are considered to be the standard of care when using lasers in dentistry [8]. The LSO is the ''keeper of the key.'' Keeping the key in a secure place allows only trained, authorized personnel to operate the laser. If the safety

practices are not being followed, then the LSO has the authority to shut down the laser operation.

The LSO must ensure that the "laser in use" sign is posted in a highly visible area to limit the access of others into the treatment room. The sign should include the danger logo, indicate visible or invisible laser light (ie, specific wavelength), and the classification. No one is allowed in the near proximity of the surgical field unless authorized and wearing the specific protective eyewear.

The LSO should be familiar with the operator's manual and safety procedures including the manufacturer's recommendations for maintenance, documentation of that maintenance, and the adverse-effects reporting mechanism. The LSO also oversees inventory and maintains laser supplies and accessories and is the person responsible for supervising staff education and training [9]. It is highly recommended to cross-train the entire staff in the event of an absence, therefore having an LSO capable of ensuring a safe environment at all times. This individual also must be familiar with the organizations that have safety guidelines and must adhere to those guidelines.

There are many practical details of an LSO's role in adhering to the safety control measures associated with a specific instrument. These responsibilities encompass the assembly and operation of the laser delivery system. First, the integrity of the delivery system must be inspected. The coupling mechanism at the laser aperture should be clean and secure; if it is not, then an error message likely will be displayed on the control panel. After the instrument is powered on and has finished its self-diagnostic testing, the laser will rest in standby mode. At this point, the LSO could perform two procedures; the first is a test fire and the second is a cleave check.

A test fire checks the integrity of the laser delivery system and is performed outside the patient's mouth and before any surgery. Typically, fiber-delivered lasers are tested by activating the surgical beam at a prescribed setting while tapping the tip of the fiber lightly against a disposable surface, such as a note pad or articulating paper. Erbium lasers and the carbon dioxide laser can be checked in similar manner by using a moistened cotton swab or a wooden tongue depressor. Obvious interaction of the laser light with the surface is an indication that the delivery system is intact and operating properly. An absence of interaction indicates improper setup or a defective delivery system. Appropriate laser safety eyewear must be worn during this procedure.

The LSO must inspect the bare fiber end or glass tip before starting the procedure. A bare fiber must have an adequate cleave, and the rigid glass tip should be flat. Inspection can be completed by holding the end of the fiber perpendicular and approximately 0.25 in (0.6 cm) away from a flat and symmetric surface. With the aiming beam turned on (but without activating the laser energy), a round red or white circle with no tails should be seen.

Any irregularities in the shape of this beam demonstrate that the cleave is faulty or the tip is flawed and should be immediately recleaved or changed to ensure that maximum energy and precision will be delivered.

Another procedure that needs to be conducted is a calibration check to determine the performance of the laser cavity and the delivery system. Some lasers have a calibration port at which the emission (distal) end of the delivery system is inserted. The laser energy is then activated, and the light transmission checked. If the laser does not have this system (which is not common on some fiber-optically delivered devices), then a power meter should be used. The LSO can activate the laser with a low power setting, direct the beam toward the meter's sensing pad according to manufacturer's directions, and look at the reading. A discrepancy in output readings between the power meter's display and the laser's control panel display indicates a loss in efficiency. If the laser has a rigid glass tip, then it should be interchanged with a new one; if the laser has a bare fiber, then it should be recleaved. The measurement should be repeated. In the case of a bare fiber, when significant differences in power readings continue, the fiber must be replaced. Similar problems with other types of delivery systems will require replacement of the affected components. With hard tissue lasers, for example, the handpiece may contain reflective optics that must be kept clean or they will be damaged permanently and must be replaced.

The LSO must know and understand the treatment objective and the proper control panel settings to achieve that goal [10]. During a laser procedure, the tips or the fiber can become coated with moderate amounts of coagulum. If the surgery continues with this material on the delivery system, then some of the laser energy will be absorbed into the coagulum, with less available for the target tissue (Fig. 1). Efficiency, precision, and visibility decrease. When this situation is observed, the LSO should ensure that the end of the fiber is cleaned, recleaved, and re-evaluated, or in some cases, the glass tip is changed.

In addition to having all safety practices employed during laser use, high-volume evacuation must be present at all times to contain the laser plume and objectionable odors [11,12]. High-volume evacuation also acts as a cooling agent by drawing air across the surgical site. The laser plume may contain many biohazards and, to protect the respiratory system, a surgical mask must be worn. To have proper filtration to remove the bacterial and viral components such as HIV, human papillomavirus, and hepatitis B virus that may be found in the plume, the mask must have the capacity to filter particles as small as 0.1 μm [13].

Fire and explosion hazards

Fire hazards associated with class IV lasers take many forms [14]. Proper procedure to minimize this kind of problem should include the following:

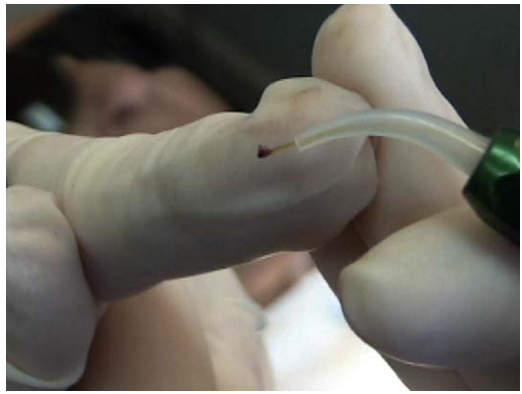

Fig. 1. A bare fiber optic showing coagulum accumulation on the tip. This coagulum must be removed before resuming surgery.

- Use only wet or fire-retardant materials in the operative field.
- Use only noncombustible anesthetic agents.
- Avoid alcohol-based topical anesthetic.
- Avoid alcohol-moistened gauze while firing the laser.
- Protect tissues adjacent to the surgical site.
- Know location and operation of the nearest fire extinguisher.
- Store highly combustible or explosive materials outside the nominal hazardous zone.
- Adhere to the ANSI directive: ''Nitrous oxide supports combustion and should not be used. . .during laser surgery'' [6].

It should be noted that, as of this writing, Z136.3–1996 [6] is the most current document that ANSI has published. As always, the reader should stay informed by obtaining future editions of the Standard and all regulations regarding the safe use of dental lasers.

Connections and traffic

All lasers require a cooling system; some use an internal fan and others use a fan and a radiator with self-contained coolant. Some class IV lasers require an external source of water or air to be supplied. If so, it is imperative that the lines are connected properly and that those utilities are turned on before powering up the laser. Electric power cords and the footswitch cable also should be inspected each time to make sure that they are in safe condition.

The laser and the associated hook-up components must be kept out of the mainstream of traffic. Fiber-optic delivery systems may need special attention because they can be up to 3 m long and, therefore, can drape easily from the emission port to the floor. The LSO must take care to not

allow equipment casters to roll over the fiber, causing its breakage or damaging other supply lines.

Eye protection

Awareness of the first type of eye protection can be traced back to 1962: with the development of the ruby laser, it was realized that lasers presented unique, specific hazards to the human eye. Lasers produce an intense, highly directional beam of light that is absorbed to some degree if directed, reflected, or focused on an object.

The eye is a critical target for laser injuries. The dentist, assistant, patient, and others who are inside the nominal hazard zone are at risk from the direct and reflected radiation of class III and class IV lasers [15]. Wearing the correct protective eyewear when using dental lasers is essential because different available wavelengths can and will damage various parts of unprotected eyes quickly.

For example, the cornea, consisting mainly of water, absorbs the emission wavelengths of carbon dioxide, erbium:yttrium-aluminum-garnet (Er:YAG), erbium,chromium:yttrium-scandium-gallium-garnet, and holmium:yttrium-aluminum-garnet lasers. In these cases, corneal burn is the recognized eye hazard.

The erbium and holmium lasers also affect the unprotected aqueous and vitreous humor and lens of the eye, leading to aqueous flare and possibly contributing to cataract formation.

Retinal damage occurs primarily with lasers that have more depth of penetration and are highly absorbed into pigment. These lasers have shorter wavelengths and include argon, helium-neon, diode, and Nd:YAG. The additional focusing effect of the cornea and lens concentrates the laser beam, which means that retinal damage can occur even from a very low-powered laser. In fact, the retina is approximately 100,000 times more vulnerable to injury than the skin within the retinal hazard range (wavelength emission of 400–1400 nm). Laser-induced retinal damage usually results in irreversible loss of visual function.

Generally, protective glasses must have an optical density (OD) of at least 4 for the particular laser emission and device [16]. Eye protection manufacturers, however, must comply with the standards of the regulatory agencies when calculating the exact OD that provides the correct amount of attenuation for protection of the specific wavelength in question.

Laser safety glasses must protect the eye structures from the specific wavelength in use, and the information about lens protection must be imprinted on the frames of the glasses or goggles (Fig. 2). The actual color of the lenses themselves is not a reliable indicator of wavelength protection or OD requirement. The LSO always should check to make sure that everyone within the hazardous zone is using the correct eyewear before the

Fig. 2. Information about eye protection printed on the safety glasses must include the optical density and protected wavelengths, as shown.

laser is activated. This practice is especially important if there are multiple laser instruments in the office or clinic.

To illustrate further, although Nd:YAG lasers at 1064 nm and diode lasers at 830 nm have similar damaging effects on the retina, there is different, specific eyewear for each of those wavelengths. In addition, the generic name of the laser device can include different emission wavelengths. In other words, if you are using a diode laser, then the glasses must provide the appropriate protection for that particular model, either in the 800-nm range or in the 980-nm range. Eyewear designed to have adequate protection for one wavelength could have completely inadequate protection for another wavelength.

Different types and styles of laser eye protection are available commercially. Some glasses now have lenses that are almost transparent, as opposed to the dark lenses that can be more difficult to see through. All glasses, however, must have side shields to protect the eyes from reflective laser energy.

Regardless of the eye protection, a practitioner never should look directly at the laser beam. Activating the laser beam at times other than the test fire or toward the intended target tissue is unsafe and poses real direct or reflective beam hazards.

The nominal hazard distance at maximum output of the laser beam varies with each wavelength, and that distance is specified in the operator's manual of the laser instrument. The LSO should have knowledge of these regulations.

Sterilization and infection control

Steam sterilization is the standard of care [17]. The small flexible optic fibers, handpieces, or tips must be steam sterilized in separate sterilization pouches after each use. They should be kept in the sterilization pouch until

ready for use. It is essential that when using fiber-optically delivered lasers, the port (connecting) end remains clean and oil-free. Therefore, never run the fiber in a sterilizer cycle alongside a high-speed turbine with lubricant. If an instrument was used to cleave or recleave a fiber during or after a procedure, then it also must be steam sterilized.

The protective housing around the laser, including the control panel and articulating arm (if applicable) should receive the spray disinfectant/wipe/spray disinfectant decontamination method, as do the dental cart and counter tops. Some delivery system components such as the large-diameter erbium fiber-optic cable are not designed for steam sterilization and must be disinfected in this way.

Adverse events

The FDA has in place a medical device reporting mechanism, whereby adverse events can be recorded and then corrected [18]. An adverse event is defined as a serious and undesirable patient experience that results from a medical instrument or product marketed in accordance with the standards set forth in the 510 (k) [2]. Such events include death, life-threatening injury, disability, hospitalization, intervention required to prevent those outcomes, and congenital anomaly possibly caused by the interaction of the instrument or product during pregnancy, resulting in a birth defect. Specific device problems such as defects, safety, or performance also are reportable [19].

When faced with such an event, the clinician should manage the patient and shut down the laser. After ensuring adequate emergency care and a safe environment, the practitioner should contact the manufacturer who will then report the incident. Clearly, the LSO would supervise the entire scenario.

How safe are dental lasers?

Staying informed and involved with the newest information, research, and outcome of particular studies is one of the most important responsibilities of the LSO. The professional literature repeatedly demonstrates the safety and effectiveness of dental lasers. Aoki et al [20] compared a conventional handpiece to an Er:YAG laser for caries removal in vitro. These researchers concluded that the laser provided effective ablation of carious dentin, with minimal thermal damage to the surrounding intact dentin and a much lower degree of vibration. Fife et al [21] demonstrated that the Er:YAG laser with air/water coolant did not increase the pulpal temperatures of any of the teeth and, in fact, decreased the pulp chamber temperature by as much as 5°C. Undesirable thermal effects such as surface cracking or carbonization were not observed with erbium lasers by Tokonabe et al [22]. Lin et al [23] examined the pulsed Nd:YAG laser and demonstrated that it is equally or more effective in significantly reducing

and inhibiting the recolonization of bacteria in a periodontal pocket up to 56 days, the length of the study.

When examining the scientific references about laser usage, it is highly advisable to read the entire study, not just the conclusion, because some crucial information could be overlooked. For example, Kreisler et al [24] researched the effect of diode laser irradiation on the survival rate of gingival fibroblast cell cultures. The aim of this in vitro study was to evaluate the effects of a diode laser in a monocell layer. The power settings were 0.5 to 2.5 W, and an exposure time of 60 to 240 seconds was used. The conclusion of these investigators was that the laser beam may cause damage to collateral periodontal tissue if the power setting and duration of treatment parameters are excessive. An LSO reading their article should ask questions about the parameters used, keeping in mind that the power settings and tissue exposure time sometimes are different in a laboratory setting. In any surgical setting, however, when the LSO identifies damage to the target tissue or adjacent tissues or when any or all the safety practices are not in place, he or she has the authority to suspend, restrict, or terminate the operation of the laser.

Summary

When it comes to laser safety, there are no compromises. This article details the information and guidelines about laser safety that dental practitioners should understand before activating any laser within the practice. At first, it may seem a bit overwhelming but it is hoped that the dental team will realize how easily laser safety can become part of daily routines. As a registered dental assistant and an LSO, it gives the author great joy to be part of this cutting-edge technology. Dental professionals who use lasers are able to offer and deliver a different kind of dentistry than the mainstream. Moreover, patients like offices with continuity, professionalism, confidence, and knowledge of safety protocols and the newest techniques. Lasers in dentistry offer incredible precision, less pain, faster healing, and of course, safety.

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